

Helios Mission Support

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Project Helios is a joint Deep Space Project between the Federal Republic of West Germany and the United States. Two solar orbiting spacecraft are planned: the first to be launched in mid-1974 and the second in late 1975. The spacecraft will have a perihelion of approximately 0.25 AU and an aphelion of 1.0 AU. These highly elliptical orbits will come closer to the Sun than any known or presently planned deep space venture to date. Prior volumes of this report have provided the reader with an overview of the division of responsibilities between West Germany and the United States, the Project management organization, and the spacecraft design—including a functional description of its radio system and the latter's interface with the Deep Space Network. This article highlights the supporting activities of the TDS organization during the Fifth Helios Joint Working Group meeting, which was held October 20–27, 1971 at Oberpfaffenhofen (southwest of Munich), West Germany.

I. Introduction

References 1–5 provided an overall management, technical and mission description of the *Helios* Project and its spacecraft. Except for minor changes, this material is expected to remain valid until the prototype spacecraft has been fabricated—at which time near-final parameter values will become known. This article and its sequels will deal with the bimonthly activities of the DSN in the support of Project *Helios*. Specifically, this article treats the DSN activities in support of the fifth Helios Joint Working Group meeting held at Oberpfaffenhofen (near Munich), West Germany, October 20–27, 1971.

II. Highlights of Tracking and Data System (TDS) Status Report, Fifth Helios Joint Working Group (HJWG) Meeting

A. Support Instrumentation Requirements Document (SIRD)

Though not a TDS responsibility, the publication by the Project Office of the *Helios* preliminary Support Instrumentation Requirements Document (SIRD) in September 1971 represented an important milestone on the NASA/TDS schedule. This document sets forth *Helios* Project requirements upon the ground tracking and data acquisition facilities, including the Deep Space Network.

This issue of the SIRD is considered preliminary only in the sense that either certain project parameters have not yet been determined, and/or that certain support requirements have not yet been negotiated with the TDS organization. Factors such as these are to be expected in an initial issuance of a document—especially one of such overall magnitude as the SIRD. Despite the foregoing exceptions, the *Helios* preliminary SIRD is a well-written and quite definitive document. As such it will permit the TDS organization, and in particular the Deep Space Network, to develop realistic plans concerning the manner by which the various ground tracking networks will support the *Helios* Project. These plans will be delineated in the NASA Support Plan (NSP). Like the SIRD, the NSP will be first issued in preliminary form, then subsequently issued in final form in response to the final SIRD. Therefore, the issuance of the *Helios* preliminary SIRD in time for the Fifth Joint Working Group meeting represented a very important milestone in the evolution of this project.

B. Near-Earth Phase Study Group

The second item reported to the opening general session of the Fifth *Helios* Joint Working Group meeting related to the TDS organization support of the *Helios* "Near-Earth Phase Study Group." This was a special study group that was established within the overall joint working group organization (Fig. 1, p. 20 of Ref. 1). Its purpose was to take an initial look at the near-Earth phase sequence of events to determine the feasibility of activating selected onboard scientific experiments during the cislunar portion of the spacecraft trajectory. Certain experimenters desire to make measurements of the various shock fronts surrounding Earth in the region between 13 Earth radii and lunar distance. Since this same portion of the trajectory contains the Step I and Step II spacecraft maneuvers (Ref. 1, pp. 24–25; Ref. 2, pp. 21–23) it was necessary to establish a special study group whose membership was comprised of representation from each of the subgroups depicted in Fig. 1 of Ref. 1. Toward this end, the study group selected the arbitrary example of a 60-deg direct ascent launch using a *Titan Centaur* TE 364-4 launch vehicle configuration. While the details of this study are provided in the minutes of the second special meeting (Ref. 6), the study group did conclude that for the case selected it was feasible to consider the operational possibility of activating selected science instruments during the cislunar portion of the spacecraft trajectory.

C. DSN Trainee Program

As part of the international agreement between the United States and the Federal Republic of Germany, NASA agreed to train selected West German technical personnel at appropriate NASA field installations for a period of one year each (Ref. 1, p. 19). A majority of these West German technical personnel have been assigned to either the Goddard Space Flight Center or to the Jet Propulsion Laboratory since the program was initiated in 1969. During the six-month period preceding the Fifth *Helios* Joint Working Group meeting, eleven *Helios*/DSN trainees were in residence at JPL. Of this number, five represented new arrivals while six were completing their year's residency at the Laboratory as of that date. The DSN trainee program has been very successful with most, if not all, of its "graduates" assuming positions of high responsibility upon their return to West Germany. In addition, it has generated an air of comradeship among both the U.S. and German participants in this program. This is especially noticeable during the *Helios* Joint Working Group meetings, and is an element in the strong team spirit that is developing within the *Helios* Project.

III. Highlights of the TDS Subgroup Activities at the Fifth Working Group Meeting

The TDS subgroup is composed of seven permanent members. The U.S. representation consists of the NASA *Helios* TDS manager (JPL) who acts as the chairman of the subgroup, the DSN Manager for Project *Helios* (JPL), and a representative of the NASA Data Center (GSFC). The remaining personnel are West Germans who represent either the Deutsche Forschungs-und Versuchsanstalt fuer Luft-und Raumfahrt E.V. (DFVLR)—German Research and Experimental Institution for Aerospace—or the Gesellschaft fuer Weltraumforschung, mbH, (GfW)—Society for Space Research—portions of the West German Project organization. The subgroup meetings to date have concentrated on the following topics:

- (1) The planned capabilities of the DSN to support Project *Helios*.
- (2) West German plans to implement tracking facilities at Effelsberg (near Bonn) and Weilheim (south of Munich).
- (3) The design and implementation of the German Space Operations Center (GSOC) at Oberpfaffenhofen (southwest of Munich).
- (4) The design of the interface between the GSOC at Oberpfaffenhofen and the SFOF at JPL.

- (5) The preparation of the Experiment Data Records (EDRs)—both U.S. and German.
- (6) Miscellaneous problems such as obtaining West German government permission to operate on the (DSN) assigned *Helios* frequencies within that country.

Discussion of the above topics continued during the Fifth *Helios* Joint Working Group Meeting, since they are of a continuing nature.

It was reported that the DSN is presently in an operational mode for *Mariner* Mars 1971 and simultaneously undergoing preparations to be ready for the launch of the *Pioneer F* spacecraft during the first quarter of 1972. Since the *Helios* requirements upon the TDS are quite similar to those of *Pioneers F* and *G*, it was felt that the DSN capabilities and performance would be well established by the time of the *Helios A* launch in mid-1974.

The Max Planck Institute (MPI) 100-m radio-telescope at Effelsberg, West Germany, is presently undergoing acceptance testing and evaluation by MPI. The DFVLR has made arrangements with MPI to utilize the 100-m telescope in support of Project *Helios*, and has received funding to initiate studies that will lead to procurement specifications for the additional equipment necessary for the 100-m Effelsberg antenna to support *Helios* as a "receive-only" facility.¹

The DFVLR plans to install a telecommand (transmit) tracking facility² at Weilheim (south of Munich). The antenna, which will be approximately 30 m in diameter, will be located on the same property as the present ZDBS³ German Satellite Tracking Station whose control room facilities will be expanded to handle the additional antenna. Functional specifications for this station are now being prepared, prior to the solicitation of competitive bids.

Network control for these two stations will be conducted from GSOC,⁴ Oberpfaffenhofen (southwest of Munich), along with *Helios* Mission Operations during Phases II and III. Plans are now under way for the building, computer and Mission Support Area expansion of GSOC in preparation for *Helios*.

The DSN has assigned *Helios* S-band channels 21A and B for Flight A and Channels 15A and B for Flight B. Since these channels are within the present DSN allocated frequency bands, there is no frequency allocation problem with respect to stations within the Deep Space Network. However, the stations in West Germany are new and have not received prior frequency allocation to operate in the DSN frequency band. A frequency authorization request has been submitted to the Deutsche Bundespost who now has the matter under consideration. The Bundespost principal concern regarding the Weilheim facility is the possibility of future radio-frequency interference to the many microwave relay links in the area that operate in this portion of the spectrum. The Project concern with respect to the Effelsberg facility is possible future interference from aircraft radar and navigation sources and/or microwave relay link transmitters in that area which might degrade the station's capability to receive *Helios* signals.

Another important topic discussed during the TDS subgroup meeting is how the telemetry, command, tracking, etc., data processed by the U.S. and German Tracking Networks was to be compiled, forwarded to the GSFC and GSOC space data centers, subsequently collated into separate data files, possible mathematical computations performed, then formatted and placed into an individual log for each experimenter. This had been an open matter for several Joint Working Group meetings. However, a logical solution was achieved at the Fifth Joint Working Group Meeting: each experimenter who has an instrument onboard the spacecraft will receive two types of computer magnetic tapes—one containing all of his experiment's data plus command information and those spacecraft engineering (housekeeping) telemetered parameters he specifies; and the other tape containing the spacecraft trajectory data and its position relative to the Sun, Earth, and other bodies in the solar system. In addition, the TDS subgroup agreed upon a standard format for placing the data onto the magnetic tapes (Ref. 7). The concept was ready to present to the experimenters (see *Subsection IV-C* following).

IV. Highlights of TDS Joint Meetings With Other Subgroups

Following the opening general session of the *Helios* Joint Working Group Meetings, it is customary for each subgroup to conduct individual meetings (such as described in *Section III*) to discuss matters pertaining to activities within their own fields of responsibility. Fol-

¹Denoted the "German Effelsberg Station" (GES).

²Denoted the "German Telecommand Station" (GTS).

³Station's call-letters, which stand for Zentral Deutsche Bodenstation (Central German Earth Station).

⁴GSOC is located within the DFVLR Field Center at Oberpfaffenhofen.

lowing this, the subgroups meet jointly (usually in pairs) with other subgroups to discuss interface problems or other matters of common interest. This is shown diagrammatically as the sixth level of Fig. 1, p. 20 of Ref. 1. Following the various joint meetings a concluding general session for all participants is conducted prior to the close of each semi-annual *Helios* Joint Working Group Meeting. Just prior to the concluding general session, the minutes of all subgroup and joint subgroup meetings are collected and submitted to the cochairman for compilation and subsequent publishing as the official minutes of that Joint Working Group meeting. In the paragraphs that follow, the highlights of the various TDS joint sessions with other subgroups are described.

A. TDS/Spacecraft Telecommunications Joint Meeting

Due to the long development cycle, it is a characteristic of space-flight projects to place an early emphasis upon design of the spacecraft. Especially important is the early definition of the spacecraft's interface with the other elements of the Project, because they, in turn, tend to control the internal interfaces within the spacecraft and, hence, its final design. For this reason, the TDS/Spacecraft Telecommunications Joint meetings have been particularly active in the past and are expected to remain active for a considerable time in the future. By the time of the Fifth *Helios* Joint Working Group Meeting, the interface discussions had passed the conceptual stage to the actual hardware and its physical, electrical, and performance interfaces with its associated equipment. The TDS/Spacecraft Telecommunications Joint Meeting had many agenda items pertaining to the forthcoming (spring 1972) compatibility tests between the Engineering Model (EM) spacecraft transponder and the DSN. These agenda items ranged from the overall Compatibility Test Management Plan⁵ down to the level of the exact test equipment, available floor space, desks, and conference areas available at the DSN for the forthcoming EM compatibility tests. Another topic of discussion concerned the still unresolved problem of RF communication with the spacecraft after its encapsulation within the metal shroud of the launch vehicle up to the time of shroud ejection after launch. This problem is under active study by the NASA launch vehicle contractor, but its solution is of obvious interest to the TDS organization. Another ongoing discussion topic is the technique for in-flight determination of the *Helios* spacecraft attitude because the attitude, in turn, influences the received-signal strength

on the ground due to the characteristics of the spacecraft's antenna system. Topics, such as the latter two, are evolutionary in nature and become almost standard agenda items during the joint TDS/spacecraft meetings.

In addition to its problem-solving activity, the Joint TDS/Spacecraft Telecommunications meetings serve as an information exchange forum wherein both parties to the interface receive the other's technical data and thereby achieve a better understanding of the *Helios* Telecommunications System as a whole—i.e., information being recorded on a sensor onboard the spacecraft all the way through the system to a display or recording device in the Mission Control Center. Such exchanges provide the necessary reference material for the day-to-day project activity that must be accomplished between the formal, semiannual *Helios* Joint Working Group meetings.

The above are merely highlights; further information may be found in the formal minutes of the meeting (Ref. 7).

B. TDS/Mission Analysis and Operations Joint Meeting

Historically, the DSN has had two major interfaces with the flight project it is supporting. The first is with the spacecraft, as mentioned above. The second is with the Flight Project's Mission Operations Team, because the latter is both the recipient of the spacecraft telemetry data accumulated by the DSN and the originator of any command messages to be sent via the DSN to the spacecraft. In Project *Helios*, this important interface is recognized in the working group structure through joint meetings between the TDS and the Mission Analysis and Operations (MA&O) subgroups, in addition to the DSN having a regular permanent member on the MA&O subgroup panel. Also, reciprocally, the MA&O has representation on the TDS subgroup panel. As may be seen in Fig. 1, p. 20 of Ref. 1, the MA&O subgroup membership is basically derived from the *Helios Ground and Operations System* (HGOS) of the West German Project organization. In the West German Project structure, HGOS has overall management responsibility for both the *Mission Operations System* and the *German Tracking and Data System*. To separate these latter two functions within the working group structure, HGOS also has (separate) permanent representation on the TDS panel for the German Tracking and Data System facilities. To avoid unnecessary duplication, agenda items pertaining to facility or hardware implementation and/or interfaces are discussed during the individual TDS subgroup meetings, while agenda items pertaining to software or operational

⁵"DSN/*Helios* Spacecraft Telecommunications Compatibility Management Plan," Document 613-3 (JPL internal document), Sept. 15, 1971.

procedures are discussed during the TDS/MA&O joint meetings. One of the principal objectives of the TDS/MA&O meetings to date has been to ascertain whether or not the *Helios* spacecraft as it is presently designed is amenable to smoothly conducted mission operations after launch. A preliminary study of this question is dictated by the need for an early design of the spacecraft as mentioned in Paragraph A, above. This was one of the motivating factors behind the establishment of the previously mentioned Near-Earth Phase Study Group.

During the Fifth *Helios* Joint Working Group meeting, plans were made for the establishment of an HGOS/TDS management plan. Such a document is important for two reasons: first, the international character of Project *Helios* requires formal documentation; second, it is necessary to distinguish and define how the two major elements of HGOS (mission operations versus tracking operations) interface on a working or operational basis with the NASA TDS organization, since the latter has primary tracking and data acquisition responsibility for the *Helios* primary mission (Phases I and II).

Another important topic of discussion was the *Helios* Software Requirements Document (SRD), which is now scheduled for publication July 1, 1972. An outline for the contents of this document has been prepared, but there is still open discussion as to where certain computer programs should reside during Phase I of the *Helios* mission—i.e., in the German Space Operations Center (GSOC) or in the Space Flight Operations Facility (SFOF). During Phase I (which is defined as prelaunch activities through launch +2 to +4 weeks) mission operations will be conducted from the SFOF, while during Phase II through the end of the mission, mission operations will be conducted from GSOC. Since Phase I encompasses a relatively short time period—i.e., 2 to 3 months—versus some 18 months for Phase II, there are economic pressures to minimize the *Helios* software development for the SFOF computers. On the other hand, there are reliability risks associated with the concept of a mission operations team residing in the SFOF having to depend upon software programs that only reside in the GSOC computers and connected to the SFOF via overseas telephone/data circuits—especially in a real-time operating situation. This is but one example of the need for an overall TDS/HGOS management plan.

For more information on these and the other topics that were discussed during the TDS/MA&O joint meeting, the reader is referred to the minutes of the Fifth *Helios* Joint Working Group meeting (Ref. 7).

C. Highlights of the TDS/Experimenters Joint Meeting

There are ten separate experiments flown onboard the *Helios* spacecraft. However, three of these experiments are further subdivided by separate onboard instrumentation so that the total number of individual experiment packages numbers sixteen. In addition, there are two ground-based experiments (see the following) which utilize only the received *Helios* spacecraft signal to obtain scientific data pertaining to the solar system. Since each experiment involves more than one scientist, there are approximately 35 coexperimenters supporting the *Helios* science activity. While the experimenters' major interface is with the spacecraft subgroup, they also have an interface with the TDS subgroup because the latter provides them the Experiment Data Record (EDR) which contains, on an individual basis, the data each experiment accumulates during the mission. Since both the content and the procedures necessary to generate these individual EDRs had been previously evolved within the TDS subgroup meeting (see the foregoing *Section III*) the EDR concept and structure was presented to the experimenters' subgroup for their approval. Since the experimenters found no objection, the TDS subgroup will proceed to implement the EDR system as presented during the Fifth *Helios* Joint Working Group Meeting.

With respect to the two ground-based experiments, it was officially announced at the Fifth *Helios* Joint Working Group Meeting that experiment 11A, celestial mechanics, had received both U.S. and German headquarters approval. This experiment will utilize both doppler and range data from *Helios* to further refine mankind's knowledge of the properties and constants of the solar system and provide another test of Einstein's Special Relativity Theory. Also during the Fifth *Helios* Joint Working Group Meeting, a proposal was received to perform an additional ground-based experiment. The latter measures the Faraday rotation of the polarization of the received *Helios* spacecraft signal as it passes through the Sun's corona during the solar occultation portions of the *Helios* trajectory (see Fig. 3, p. 28 of Ref. 2). This would provide additional information about the characteristics and properties of the Sun's corona.

Another topic of interest to the TDS subgroup during the joint meeting was the planned location for the experimenter teams during the launch phase of the mission. The Experimenter Subgroup had previously expressed a desire for their teams to be located at Cape Kennedy in order that they might properly supervise the final checkout and calibration of their on-board instruments.

Since the experimenters want to observe the return of science data during the first seven hours after launch, they had requested that the data be transmitted to Cape Kennedy and that additional display and control equipment be located there for their use. *Helios* Project management had previously rejected this request on the basis of economic factors and the fact that actual mission operations during Phase I will be conducted from the SFOF in Pasadena, hence the experimenter teams should be situated in the SFOF. During the Fifth *Helios* Joint Working Group Meeting, Project management clarified its position by stating that, if the experimenter team could accomplish their objectives in the Cape Kennedy area by utilizing presently funded equipments planned for that area, that Project management would reconsider the experimenters' request. The matter is now under further study by the both Experiments Subgroup and Project Management. Should a solution favorable to the experimenters be found, it will be incumbent upon the TDS organization to provide a two-way data flow between the SFOF in Pasadena and the experimenter team area at Cape Kennedy, Florida.

The foregoing represents the major topics of discussion during the TDS/Experimenter Joint Subgroup Working Group Meeting. Further details on these and other topics discussed may be found in the official minutes of the meeting (Ref. 7).

D. Highlights of Performance, Trajectory and Guidance Working Group Meeting

A special working group meeting has been established under the auspices of the Launch Vehicle Subgroup for the purpose of helping to define the launch phase of the *Helios* Mission. This special working group, which is chaired by the Lewis Research Center (LeRC), is composed of representatives of both the U.S. and German *Helios* Project Offices, LeRC *Titan-Centaur* Project Office, the Near Earth Network, DFVLR/GSOC, the three launch vehicle contractors, the *Centaur* guidance contractor, and the *Helios* spacecraft prime contractor. This panel met for a full day during the Fifth *Helios* Joint

Working Group sessions. During the meeting, it was officially announced that *Helios* would employ a *Titan/Centaur*/TE 364-4 launch vehicle which would fly on the previously specified direct-ascent launch trajectory. Both LeRC and the *Centaur* launch vehicle contractor have started working on the available trajectories. The meeting disclosed that there would be problems in flying the above vehicle on a best performance trajectory for each day of the launch window if the *Titan* Stage 2 were allowed to burn to fuel depletion; for launch azimuths below 95 deg, this stage could impact Europe or Africa. To circumvent this problem, it is now planned to have *Titan* Stage 0 climb almost straight up and to have Stage 2 cut off before fuel depletion. Besides ensuring that Stage 2 will not impact land, a major benefit of this redesign on the near-Earth TDS is that the perigee altitude of the trajectory is raised from 100 to 500 nmi. This will provide much longer view periods from the near-Earth Stations. However, this benefit is not achieved without penalty, since this new trajectory will have higher initial angle and doppler rates, and the higher perigee altitude will cause more space loss attenuation of the *Helios* spacecraft signal as received by the near-Earth stations. These latter problems require further study. Nonetheless, present planning is based on the assumption that the final *Helios* A trajectories will have the characteristics listed in Table 1.

V. Conclusions

This article has attempted to present the highlights of the Fifth *Helios* Joint Working Group meeting as they relate to the activities of the supporting TDS organizations, and in particular to the Deep Space Network. Obviously, there were many other important topics discussed during the Fifth *Helios* Joint Working Group sessions, but since they did not have direct bearing upon the TDS, they were not included in the foregoing summary. Should the reader be interested in these other topics, he may find them in the formal minutes of the meeting (Ref. 7). The Sixth Joint Working Group meeting is presently scheduled for the end of April and the first part of May 1972 at the Jet Propulsion Laboratory.

References

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6. *Project Helios Minutes of Second Near-Earth Phase Study Group Meeting Held at Goddard Space Flight Center, Greenbelt, Md., May 5–7, 1971*. Goddard Space Flight Center, Greenbelt, Md.
7. Minutes of the *Project Helios, Fifth Joint Working Group Meeting at DFVLR-Center Oberpfaffenhofen, Federal Republic of Germany*, October 20–27, 1971. Published by Gesellschaft fuer Weltraumforschung, mbH, Bonn-Bad Godesburg, West Germany.
8. *Minutes of Titan/Centaur/Helios-A Performance, Trajectory and Guidance Working Group Meeting*, held October 16, 1971, Oberpfaffenhofen, Germany. Prepared by Lewis Research Center, Cleveland, Ohio.

Table I. *Helios-A* trajectory characteristics

Launch Azimuths	45 to 60 deg and 80 to 110 deg
Declination	— 23.5 deg to +12 deg
Perigee altitude	500 nmi
C3	115 to 125 km ² /s ²